Jupiter analogues and planets of active stars.

RV searches at MPIA Heidelberg

Martin Kürster
with
Maren Mohler-Fischer

(1) Jupiter analogues:

The planet search programme at the ESO CES and HAPRS.
IV. The search for Jupiter analogues around solar-type stars,
Zechmeister, Kürster, Endl, Lo Curto, Hartman, Nilsson, Henning, Hatzes, Cochran, 2012, A&A accepted

(2) A search for planets around active stars.

Mohler-Fischer, Henning, Launhardt, Müller, Guenther (work in progress)

(3) The first RV-confirmed planet from HAT-South:

HATS-1b: The first transiting plamet discovered by the HATSOUTH survey,
Penev, Bakos, Bayliss, Jordán, Mohler-Fischer, Zhou, Suc, Rabus, Hartman, Mancini, Béky, Zsurby, Buchhave, Henning, Nikolov, Csák, Brahm, Espinosa, Conroy, Noyes, Sasselov, Schmidt, Wright, Tinney, Addison, Lásár, Papp, Sári
2012, in prep.

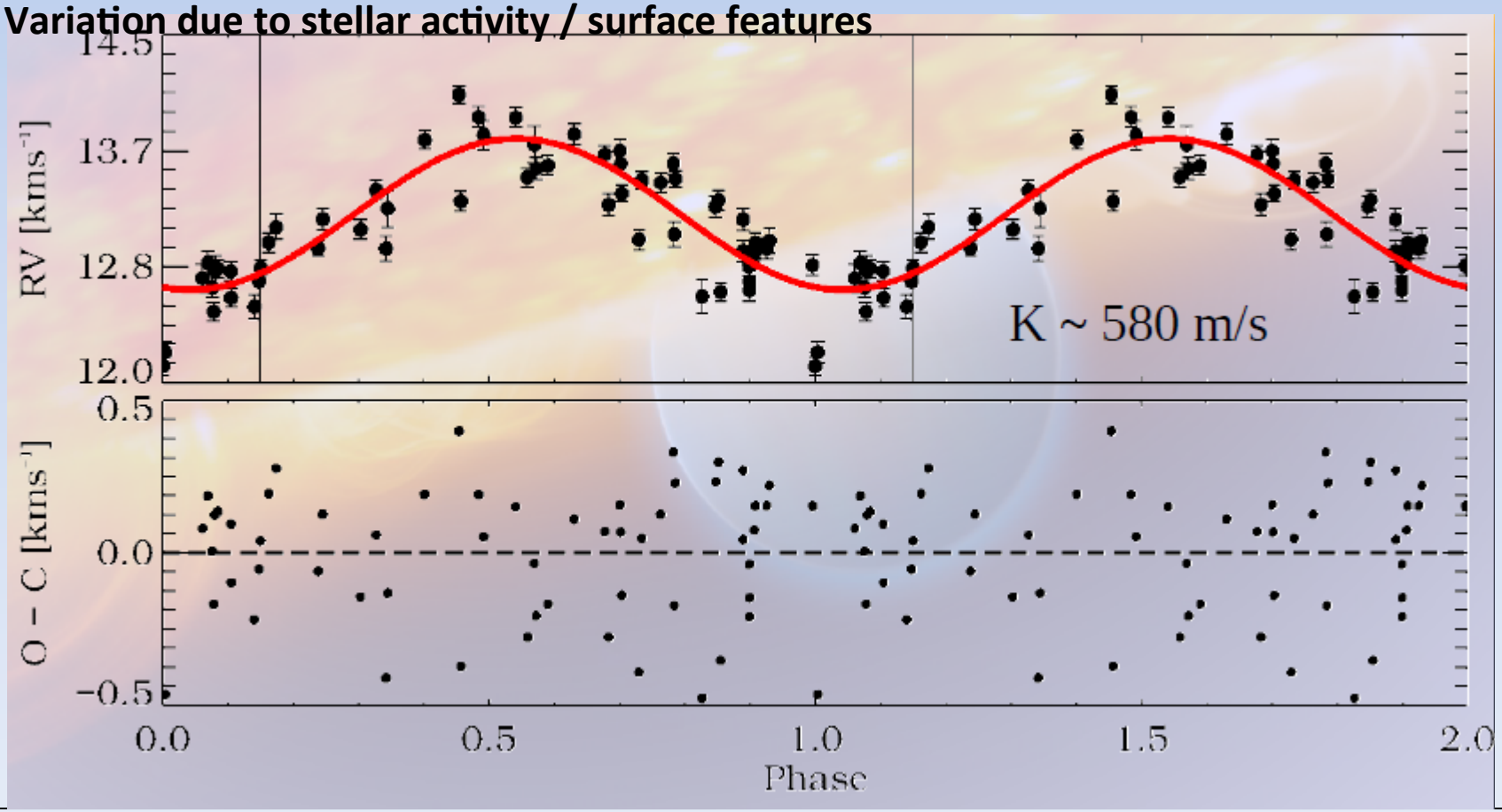
La Silla Observatory, ESO, Chile

ad (2): A search for planets around active stars.

Mohler-Fischer, Henning, Launhardt, Müller, Guenther (work in progress)

G9V star, v sin i = 20.8 km/s, 57 spectra taken with FEROS @ MPG/ESO 2.2m La Silla

Variation due to stellar activity / surface features

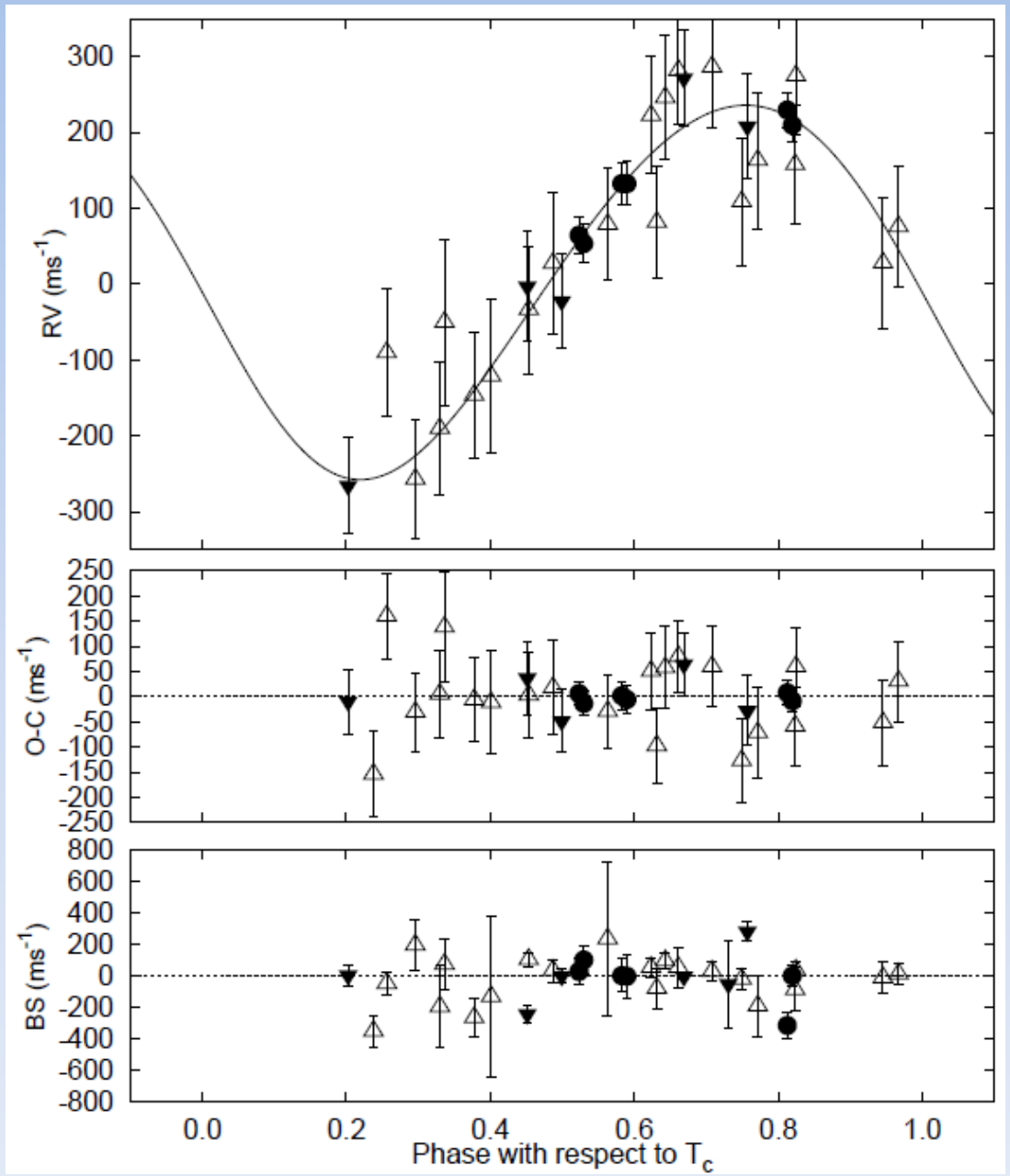


ad (3): HATS-1b

See yesterday's talk by Gaspar Bakos

RV confirmation:

CORALIE: filled circles
→FEROS: open triangles
CYCLOPS: filled triangles



Two talks you cannot miss:

Nadia Kostogryz
``A spectral differential characterization of low-mass companions´´

This afternoon, but unfortunately cancelled:

Florian Rodler
``The return of the mummy: evidence for starlight reflected from the massive hot Jupiter τ Boo b´´

ad (1): CES + HARPS RV survey

Begun in 1992,
data until 2008/2009

Bright (V<6) solar-type stars,
selected for low activity

→ Jupiter analogues

Table 1. Targets with their spectral type SpT (Hoffleit & Jaschek, 1991), visual magnitude V (Perryman et al., 1997), distance d (van Leeuwen, 2007), secular acceleration $\dot{v}_r$, and stellar mass M.

Star	alias	SpT	V [mag]	d [pc]	$\dot{v}_r$ [m/s/yr]	M [$M_\odot$]
HR77	ζ Tuc	F9V	4.23	8.59	0.84	1.06 [PM]
HR98	β Hyi	G2IV	2.82	7.46	0.86	1.1 [D]
HR209	HR 209	G1V	5.80	15.16	0.01	1.10 [G]
HR370	ν Phe	F8V	4.97	15.11	0.16	1.20 [G]
HR506	HR 506	F9V	5.52	17.43	0.02	1.17 [G]
HR509	τ Cet	G8V	3.49	3.65	0.31	0.78 [T]
HR695	κ For	G0V	5.19	21.96	0.02	1.12 [G]
HR810	ι Hor	G0V	5.40	17.17	0.06	1.25 [V]
HR963	α For	F8V	3.80	14.24	0.17	1.20 [G]
HR1006	ζ^1 Ret	G2.5V	5.53	12.01	0.61	1.05 [G]
HR1010	ζ^2 Ret	G1V	5.24	12.03	0.61	1.10 [G]
HR1084	ϵ Eri	K2V	3.72	3.22	0.07	0.85 [DS]
HR1136	δ Eri	K0IV	3.52	9.04	0.12	1.23 [PM]
HR2261	α Men	G6V	5.08	10.20	0.01	0.95 [G]
HR2400	HR 2400	F8V	5.58	36.91	0.02	1.20 [G]
HR2667	HR 2667	G3V	5.56	16.52	0.06	1.04 [G]
HR3259	HR 3259	G7.5V	5.95	12.49	0.30	0.90 [G]
HR3677	HR 3677	G0III	5.85	196.85	0.00	2.1 [G]
HR4523	HR 4523	G3V	4.89	9.22	0.53	1.04 [G]
HR4979	HR 4979	G3V	4.85	20.67	0.07	1.04 [G]
HR5459	α Cen A	G2V	-0.01	1.25	0.42	1.10 [P]
HR5460	α Cen B	K1V	1.35	1.32	0.40	0.93 [P]
HR5568	GJ 570 A	K4V	5.72	5.84	0.54	0.71 [G]
HR6416	HR 6416	G8V	5.47	8.80	0.22	0.89 [G]
HR6998	HR 6998	G4V	5.85	13.08	0.01	1.00 [G]
HR7703	HR 7703	K3V	5.32	6.02	0.37	0.74 [G]
HR7875	ϕ^2 Pav	F8V	5.11	24.66	0.24	1.1 [PM]
HR8323	HR 8323	G0V	5.57	15.99	0.04	1.12 [G]
HR8387	ϵ Ind A	K4.5V	4.69	3.62	1.84	0.70 [G]
HR8501	HR 8501	G3V	5.36	13.79	0.19	1.04 [G]
HR8883	HR 8883	G4III	5.65	101.32	0.00	2.1 [G]

References for mass estimates: [D] Dravins et al. (1998), [DS] Drake & Smith (1993), [G] Gray (1988), [PM] Porto de Mello, priv. comm., [P] Pourbaix et al. (2002), [T] Teixeira et al. (2009), [V] Vauclair et al. (2008).

CES + HARPS survey

Begun in 1992,
data until 2008/2009

Bright (V<6) solar-type stars,
selected for low activity

→ Jupiter analogues

Table 2. The three used instruments/configurations with their wavelength reference, chosen spectral coverage and resolving power, and telescope diameter.

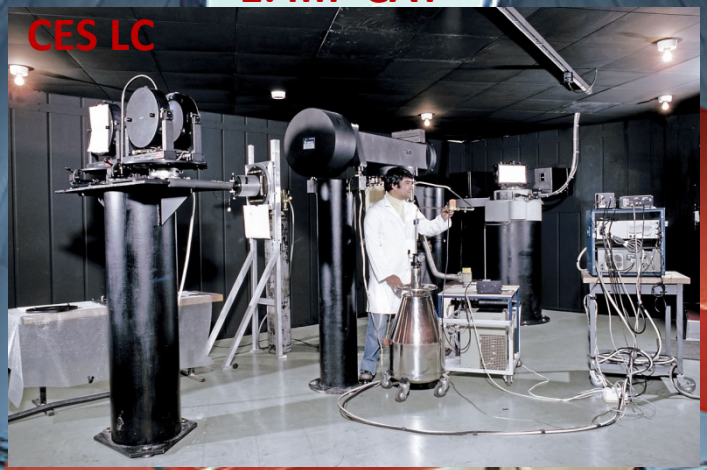
Spectrograph	Ref.	λ [Å]	R	Tel.
CES + LC	I_2	5367 – 5412	100 000	1.4 m
CES + VLC	I_2	5376 – 5412	220 000	3.6 m
HARPS	ThAr	3800 – 6900	115 000	3.6 m

La Silla Observatory

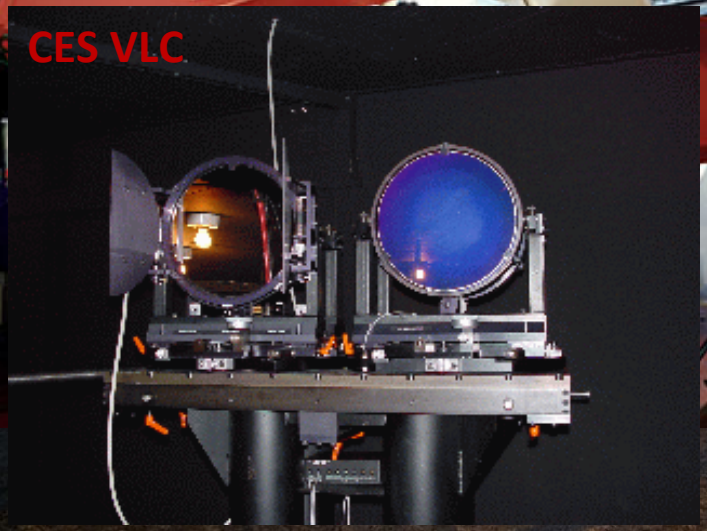
3.6m+CAT

1.4m+CAT

CES LC

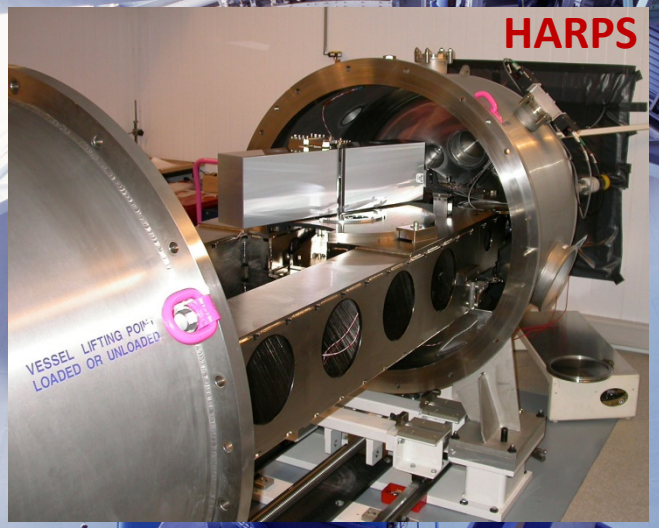


CES VLC



3.6m

HARPS

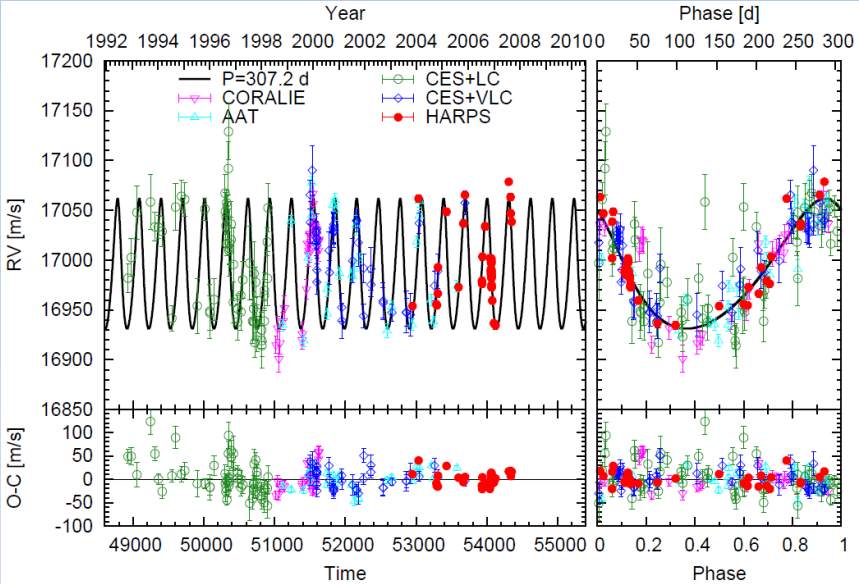


HARPS

(Co-)discoveries

ι Hor = HR 810 = HD 17051 (G0V)

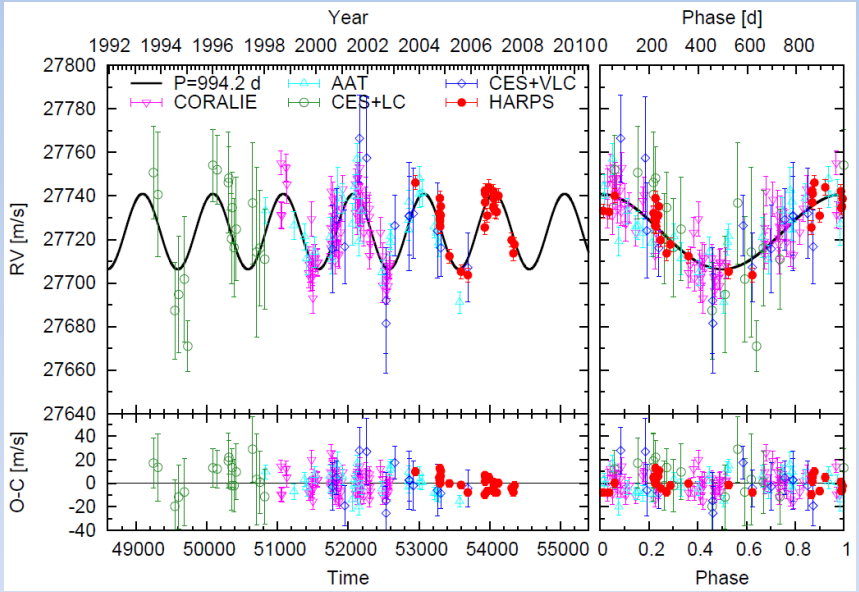
Kürster et al. (2000)



Orbital parameters for the planetary companion to ι Hor.

Parameter		Value
P	[d]	307.2 ± 0.3
K	[m/s]	65.3 ± 2.2
T_0	[JD]	$2\,449\,110 \pm 9$
ω	[°]	35 ± 10
e		0.18 ± 0.03
a	[AU]	0.96 ± 0.05
$M \sin i$	[$M_{\rm Jup}$]	2.48 ± 0.08
N		205
rms	[m/s]	14.5

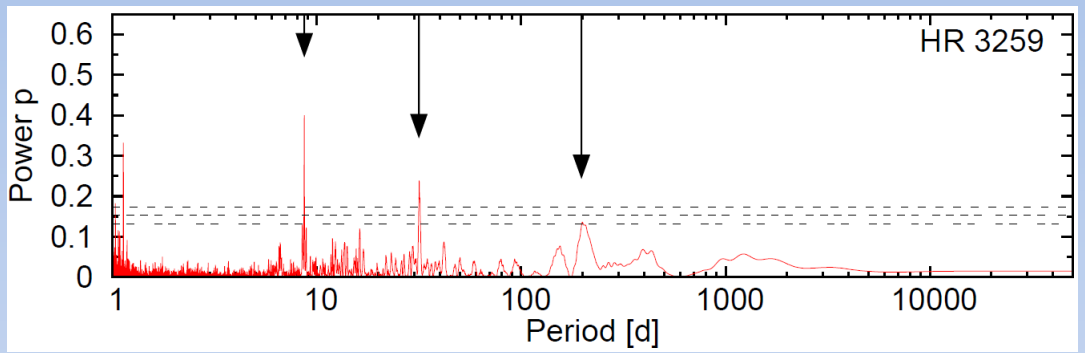
HR 506 = HD 10647 (F9V)



Orbital parameters for the planetary companion to HR 506.

Parameter		Value
P	[d]	994.2 ± 8.6
K	[m/s]	17.3 ± 1.0
T_0	[JD]	$2\,450\,088 \pm 25$
ω	[°]	0 (fixed)
e		0 (fixed)
a	[AU]	2.05 ± 0.24
$M \sin i$	[$M_{\rm Jup}$]	0.94 ± 0.05
N		158
rms	[m/s]	7.8

Confirmation



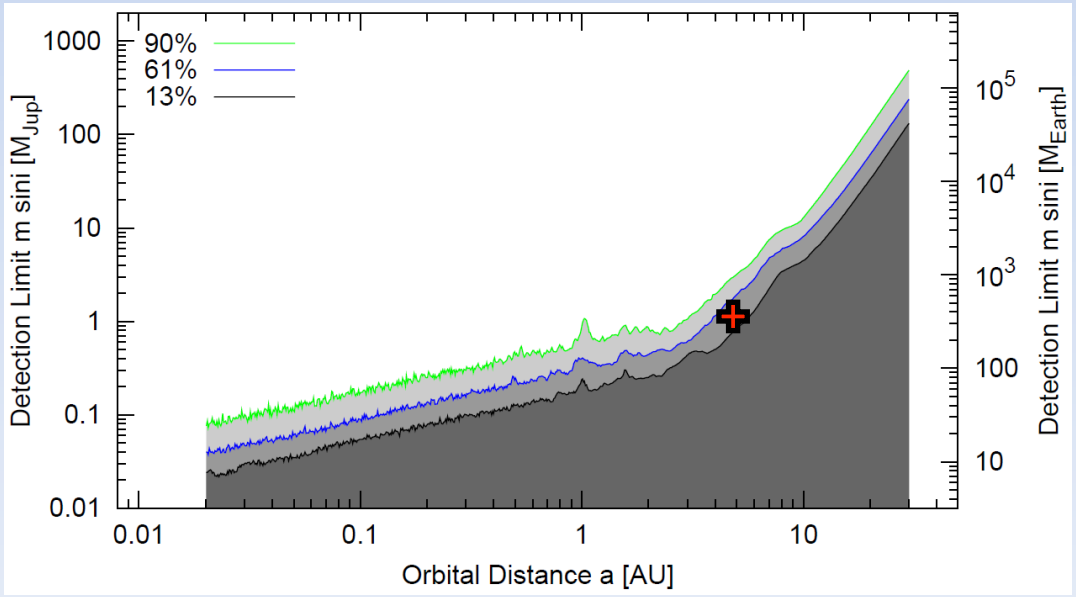
HR 3259 = HD 69830 (G7.5V)

3 planets found by
Lovis et al. (2006)

Generalized Lomb Scargle periodogram
(Zechmeister & Kürster 2009)

Levels of 1%, 0.1%, 0.01%
false alarm probability

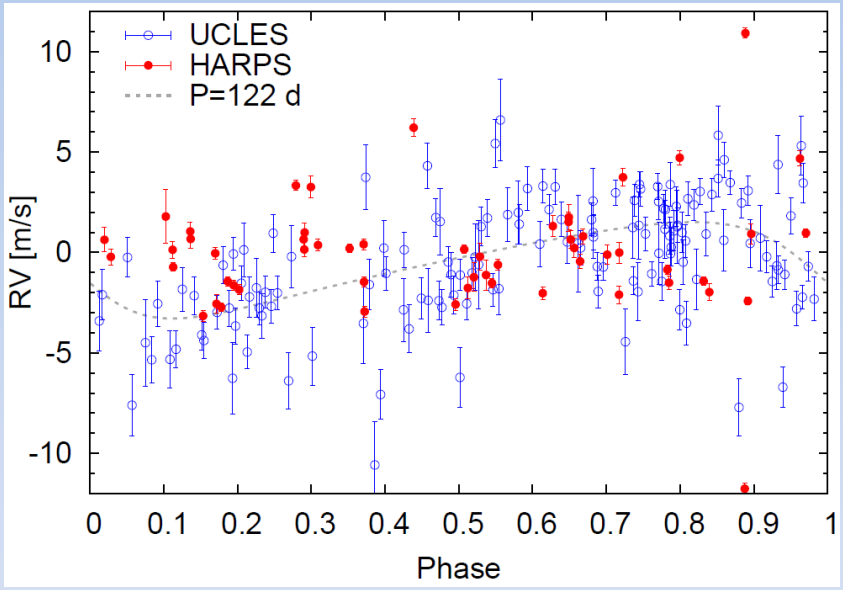
Survey sensitivity



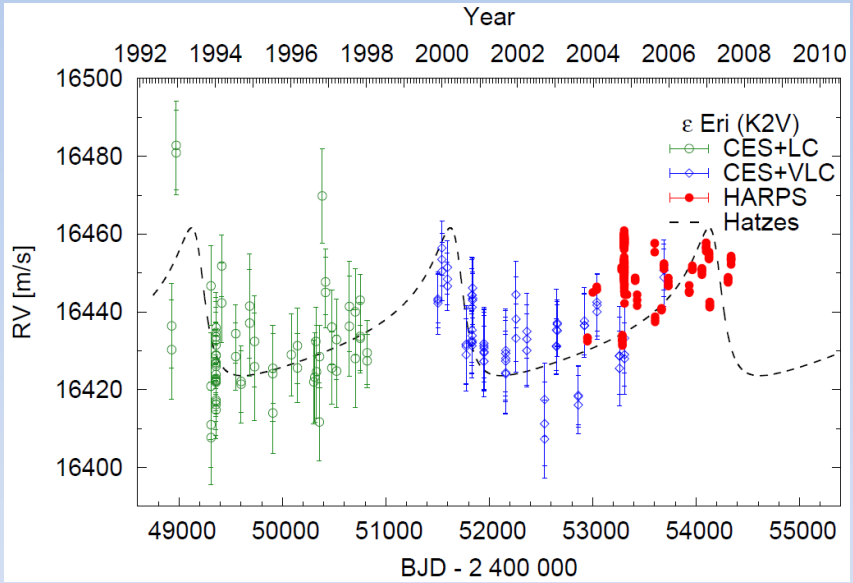
99.9% confidence
upper limits
for msini

Non-confirmations

HR 4523 = HD 102365 (G3V)



ε Eri = HR 1084 = HD 22049 (K2V)

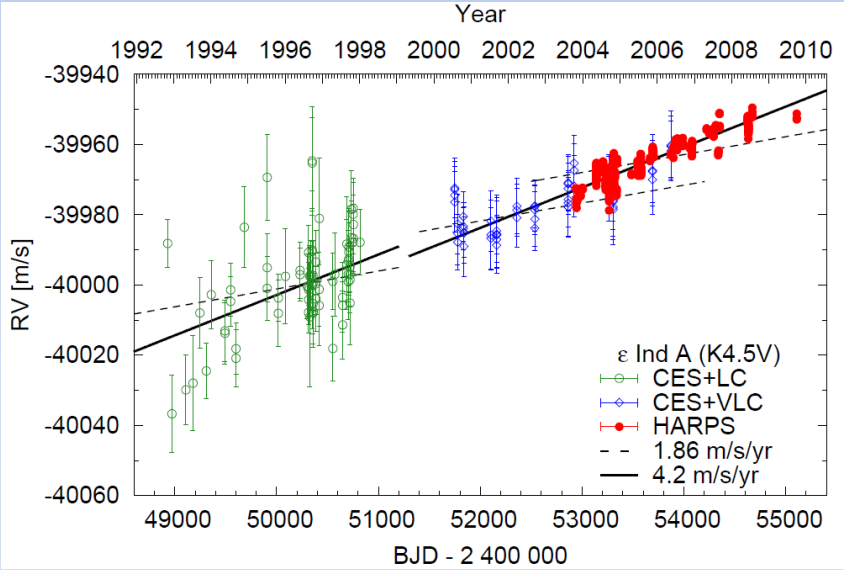


Tinney et al. (2011):
Neptune-like planet with
*m*sin*i*=16 M⊙, P = 122 d

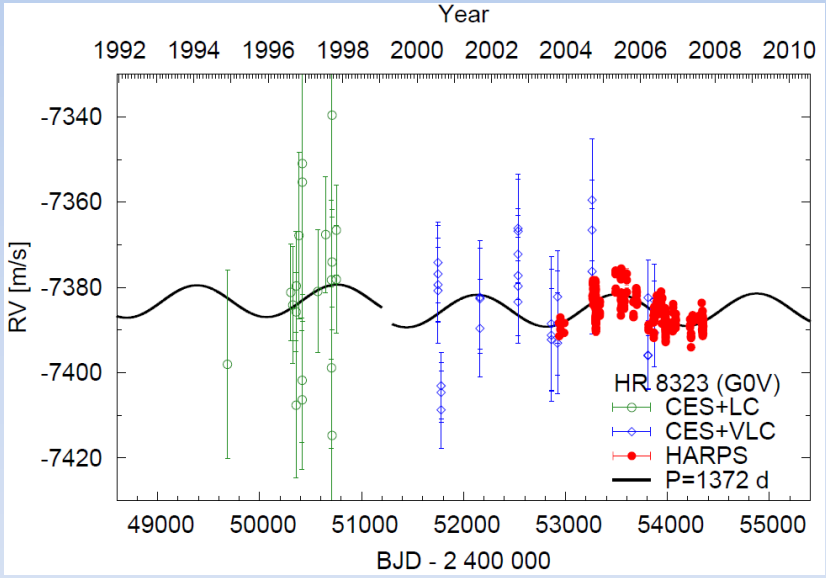
Hatzes et al. (2000):
msini = 0.86 MJup, P = 6.9 yr, e = 0.6
Benedict et al. (2006):
i=30° → *m* = 1.55 M Jup
Reffert & Quirrenbach (2011):
Upper mass limit = 6.1 MJup

Companion vs. activity

ε Ind = HR 8387 = HD 209100 (K4.5V)



HR 8323 = HD 207129 (G0V)



Dashed line: RV secular acceleration
Solid line: observed RV trend

Companion or activity?

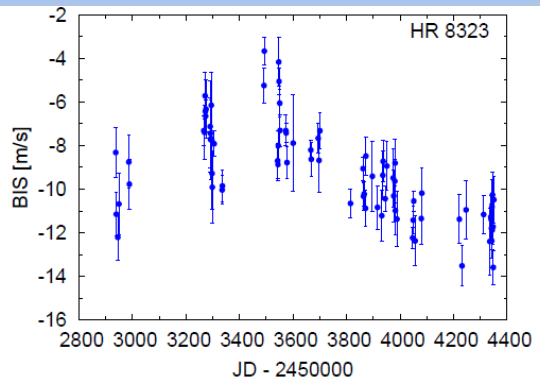
P = 3.8 yr

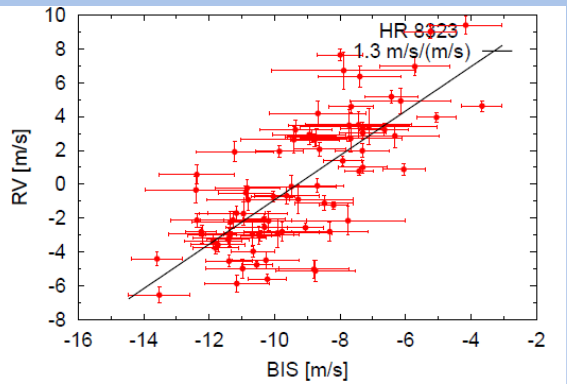
Activity cycle?

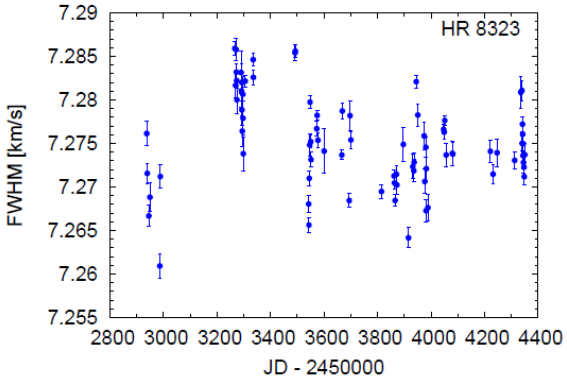
HR 8323 (G0V)

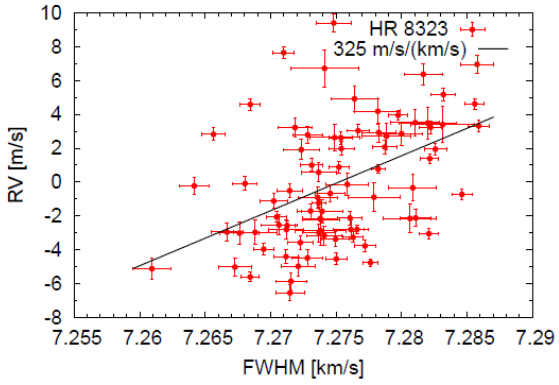
HARPS data only:

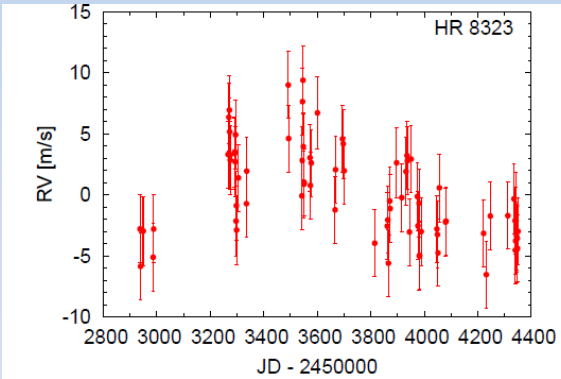
Correlations of RV with activity indicators

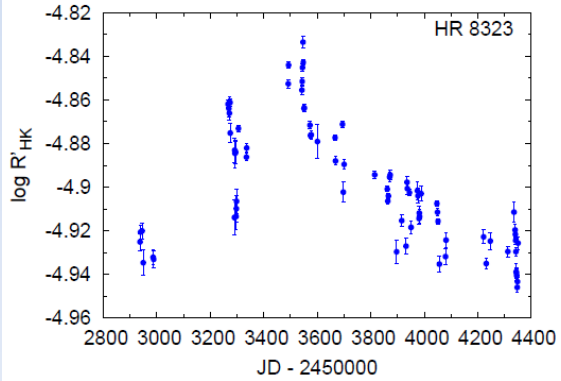


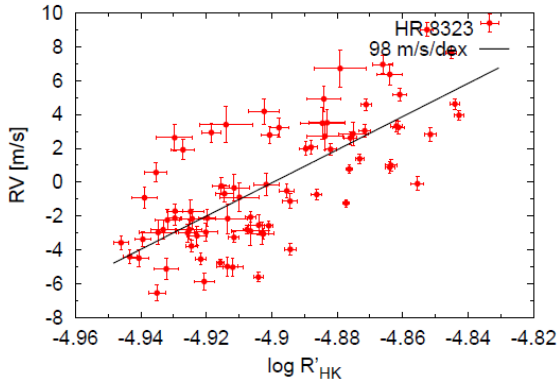












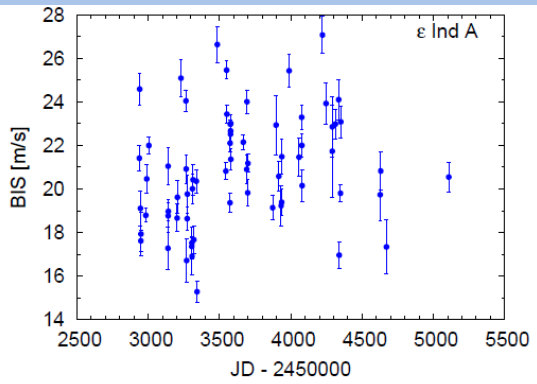
Correlations of the RV data with all activity indicators:
RV – log R‘HK
RV – BIS (line bisector)
RV – FWHM

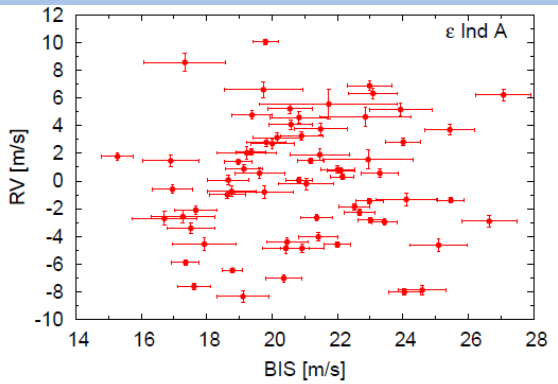
→ An active star

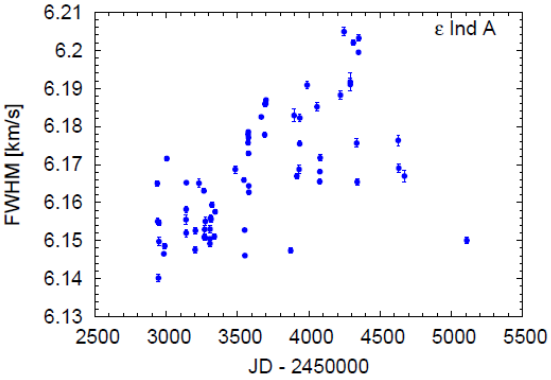
ε Ind (K4.5V)

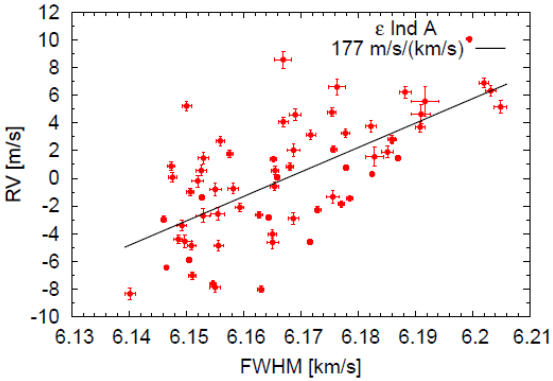
HARPS data only:

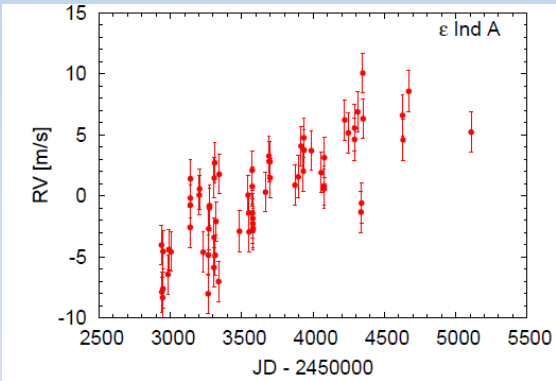
Correlations of RV with activity indicators

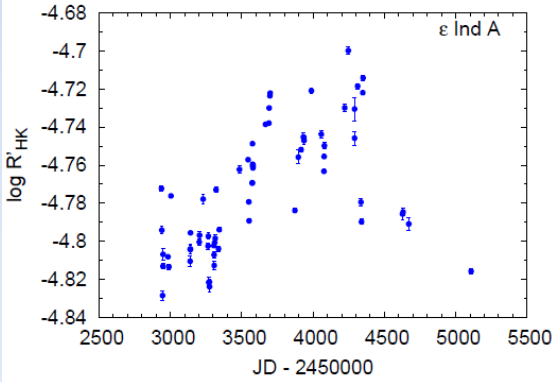


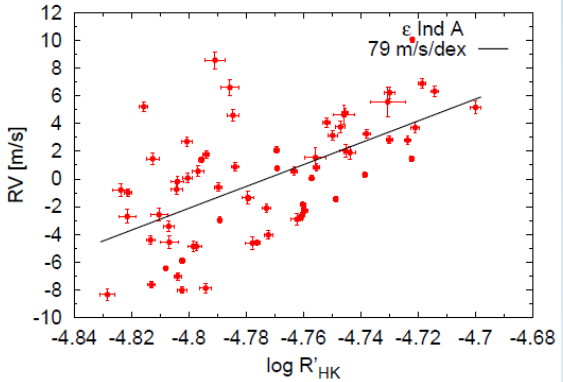












No correlation RV – BIS

Are the correlations
RV – log R‘HK and RV – FWHM
real or chance?

Active star with a companion?

Summary of the CES+HARPS survey

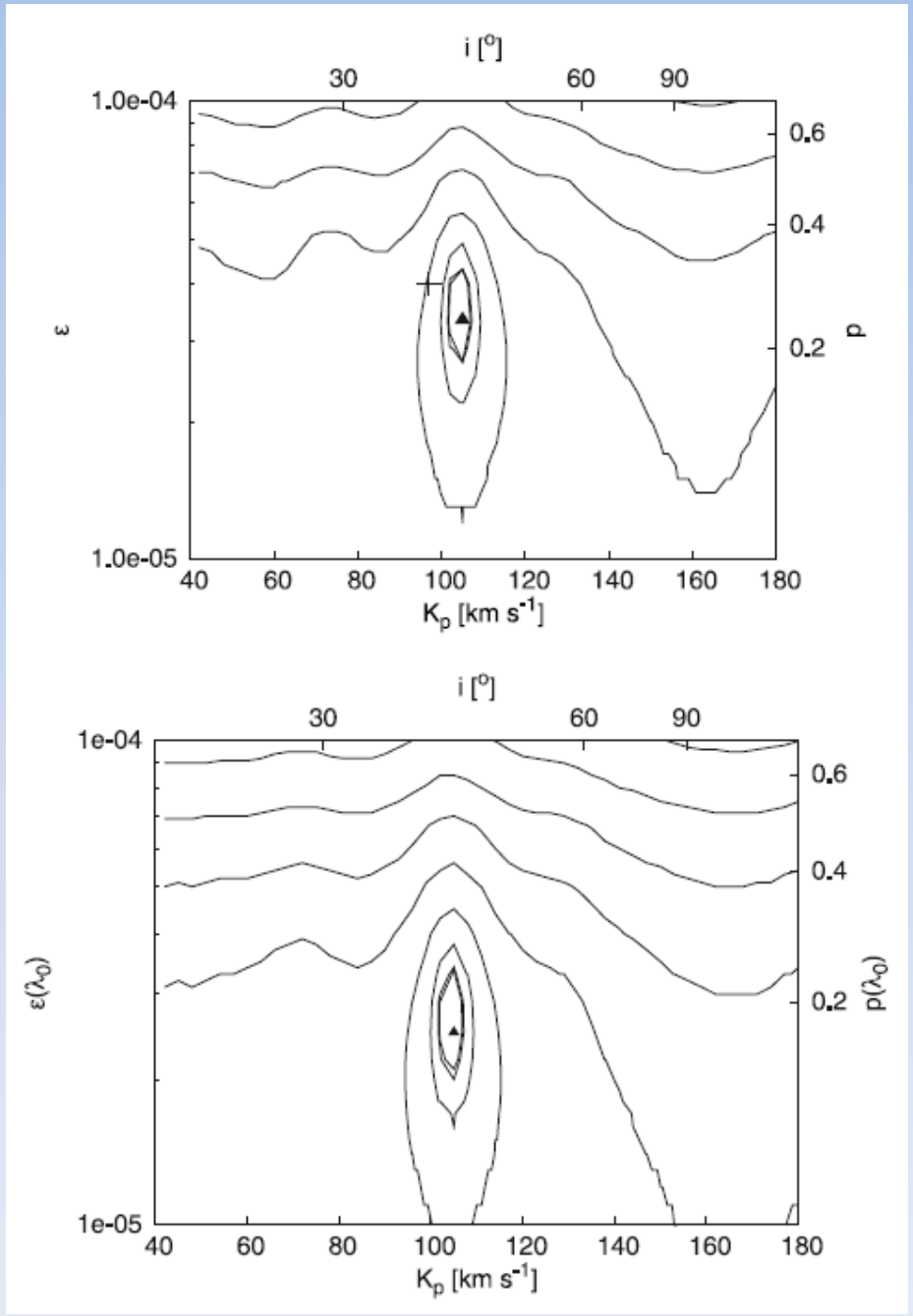
ι Hor b:	discovery – a planet around an active star
HR 506 b:	co-discovery – also a aplanet around an active star
HR 3259 b,c,d:	confirmation of three planets
HR 4523 b:	non-confirmation
ε Eri b:	non-confirmation
ε Ind:	trend that can be a companion to an active star
HR 8323:	stellar activity cycle, no companion

Florian Rodler:

The return of the mummy:

Evidence for starlight reflected from the massive hot Jupiter τ Boo b

Charbonneau et al. (1999)	τ Boo b:	$\varepsilon < 5 \times 10^{-5}$ for grey albedo, geometric albedo < 0.3 (Keck HIRES)
Collier Cameron et al. (1999):	τ Boo b:	i = 29° → m = 8 MJup (4.2m WHT)
Collier Cameron et al. (2000):	τ Boo b:	Refuted their 1999 result
Collier Cameron et al. (2002):	υ And b:	Upper limits …
Leigh et al. (2003 a):	τ Boo b:	geometric albedo < 0.39 (4.2m WHT)
Leigh et al. (2003 b):	HD 75289 b:	geometric albedo < 0.12 (ESO/UVES)
Rodler, Kürster, Henning (2008):	HD 75289 b:	$\varepsilon < 6.2 \times 10^{-5}$ for grey albedo, geometric albedo < 0.46 re-analysis of Leigh et al. 2003b data
Rodler, Kürster, Henning (2010):	τ Boo b:	$\varepsilon < 5.7 \times 10^{-5}$ for grey albedo, geometric albedo < 0.40 (ESO/UVES)
Rodler, Lopez-Morales, Ribas (2012):	τ Boo b:	CO lines @ 2.3 µm discovered with ESO/CRIRES i = 47° (+7°/-6°), m = 5.6 ± 0.7 Mjup
Brogi et al. (2012):	τ Boo b:	CO lines @ 2.3 µm discovered with ESO/CRIRES i = 44.5° ±1.5°, m = 5.95 ± 0.28 MJup
Rodler et al.:	τ Boo b:	-- Combination of various data sets -- Search for reflected light at a known RV-amplitude/inclination → Evidence


i [°]
30
60
90
1.0e-04
1.0e-05
ε
0.6
0.4
0.2
p
40
60
80
100
120
140
160
180
K_p [km s^-1]
i [°]
30
60
90
1e-04
1e-05
ε(λ_0)
0.6
0.4
0.2
p(λ_0)
40
60
80
100
120
140
160
180
K_p [km s^-1]